

EXHAUST POSITIONED AT THE DOWNSTREAM END OF A GLASS MELTING FURNACE

FIELD OF THE INVENTION

5 This invention relates to a glass-melting furnace of the type in which glass batch is deposited at one end and molten glass is removed from the other end. More particularly, this invention relates to a glass-melting furnace having at least one gas burner for melting the glass batch.

10 BACKGROUND OF THE INVENTION

 Glass-melting furnaces of many types have been commonly employed to melt glass-forming materials in the manufacture of glass products, such as fiberglass, container glass, flat glass and other types of glass. Such a glass-melting furnace typically includes a charger to introduce glass batch, at least one burner to melt the glass batch into molten
15 glass, and at least one exhaust stack to remove combustion gases from the furnace. In a cross-fired furnace, heat is introduced into the furnace from burners positioned on opposing sides of the furnace. The heat melts the glass, or batch, in the furnace. The glass batch is generally added to the furnace at the rear, or charging end of the furnace to allow for optimal melting of the glass batch to molten glass. The molten glass is removed
20 from the front, or downstream end of the furnace, through a glass evacuation channel referred to as a throat in furnaces for melting glass for manufacturing fiberglass, and referred to as a waist in furnaces for melting glass for manufacturing flat glass.

 The combustion fumes and gases released from the decomposition of the glass-forming raw materials are transferred or removed from the furnace through one or more
25 exhaust stacks positioned on opposite sides near the rear or charging end of the furnace, that is, on the opposite end of the furnace from the throat or point of glass discharge from the furnace. The reason for positioning the exhaust stacks in the rear of the furnace is to conserve energy while still maintaining acceptable melting of the batch. By exhausting the gases from of the charge end of the furnace, there is the opportunity to recover
30 significant amounts of the energy from all the exhaust gases generated in the furnace. However, positioning the exhaust stacks at the charge end of the furnace leads to batch being entrained in the gases of combustion, and thus fouling of the exhaust stacks or other

equipment, and potentially increasing the particulate from the furnace exhaust system. It would thus be desirable to design a more efficient furnace that does not have the disadvantages of known furnaces.

5 SUMMARY OF THE INVENTION

The above objects as well as other objects not specifically enumerated are achieved by a glass-melting furnace having an upstream end, a downstream end, and a roof. The upstream end is positioned upstream of the downstream end. A charger is provided to supply glass-forming material to the upstream end of the furnace. At least one
10 burner is provided to supply heat to the glass-forming material at the upstream end of the furnace. An exhaust is in communication with the downstream end of the furnace, with the exhaust being positioned downstream of the at least one burner.

According to this invention there is also provided a glass-melting furnace having an upstream end with a charge end wall and a downstream end with a discharge end wall.
15 The upstream end is positioned upstream of the downstream end. An exhaust is in communication with the furnace at the downstream end of the furnace.

According to this invention there is also provided a method of operating a glass-melting furnace having an upstream end and a downstream end. The method includes introducing glass-forming material to the upstream end of the furnace. The glass-forming
20 material is heated with at least one burner, the at least one burner being located at the upstream end of the furnace. Gases of combustion in the furnace are exhausted from an exhaust positioned at the downstream end of the furnace.

According to this invention there is also provided a method of operating a glass-melting furnace having a charge half and a discharge half. The method includes
25 introducing glass-forming material to the charge half of the furnace. The glass-forming material is heated with a plurality of burners, the burners providing energy and forming gases of combustion. The majority of the energy from the burners is introduced to the furnace in the charge half of the furnace. The gases of combustion are exhausted from an exhaust connected to the discharge half of the furnace.

30 According to this invention there is also provided a method of exhausting gases of combustion from a glass-melting furnace. The method includes introducing glass-forming material into an upstream end of a glass-melting furnace. A pressure differential between

the upstream end of the furnace and a downstream end of the furnace, with the pressure in the downstream end of the furnace being lower than the pressure of the upstream end of the furnace. Combustion fumes and gases are exhausted from an exhaust in communication with the downstream end of the furnace, with the pressure in the exhaust being lower than the pressure in the downstream end of the furnace. Molten glass is discharged from the downstream end of the furnace.

It is an object of the present invention to provide a glass-melting furnace having an exhaust positioned at a downstream end.

It is another object of the present invention to provide an exhaust positioned at a downstream end of a glass-melting furnace to increase the residence time of exhaust gases, thereby providing a more cost effective heating and melting of the glass-forming material.

Various other objects and advantages of this invention will become apparent to those skilled in the art from the following detailed description of the preferred embodiments, when read in light of the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a cross-sectional elevational view of a glass-melting furnace in accordance with the present invention.

Figure 2 is a cross-sectional plan view of the glass-melting furnace of Figure 1 taken along line 2-2, with a portion of the roof shown for clarity.

Figure 3 is a schematic elevational view of an alternate embodiment of a glass-melting furnace in accordance with the present invention.

Figure 4 is a schematic plan view of the glass-melting furnace of Figure 3 taken along line 4-4.

Figure 5 is a cross-sectional end view in elevation of an alternate embodiment of a glass-melting furnace in accordance with the present invention.

Figure 6 is a schematic plan view of another alternate embodiment of the furnace having an exhaust connected through the discharge end wall of the furnace.

Figure 7 is a graph showing the temperature profile of a prior art glass-melting furnace compared with the temperature profile of a glass-melting furnace in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to Figures 1 and 2, there is shown a glass-melting furnace 10, which can be used to manufacture fiberglass, container glass, flat glass and other types of glass. The glass-melting furnace 10 is operative to provide molten glass to a glass forehearth 12 or other glass processing equipment. In considering the figures, it will be appreciated that for purposes of clarity certain details of construction are not provided in view of the fact that such details are conventional and well within the skill of the art once the invention is disclosed and explained.

The glass-melting furnace 10 preferably includes an elongated channel 11 defined by a charge end wall 14 and a discharge end wall 16, two side walls 18a and 18b, a floor 20 and a roof 22. The roof 22 is preferably operatively connected to the first or charge end wall 14 and the second or discharge end wall 16. The charge end wall 14 is positioned at an upstream end 6 of the glass-melting furnace 10, where the glass-forming material is introduced or charged into the furnace. The discharge end wall 16 is positioned at a downstream end 8 of the glass-melting furnace 10, where the discharge of the molten glass from the furnace occurs. The upstream end 6 of the glass-melting furnace 10 is a charge end. As used in this specification and claims, the term "downstream end" means the end of the furnace from which the molten glass is discharged. The glass-melting furnace 10 is preferably made from appropriate refractory materials such as alumina, silica, alumina-silica, zircon, zirconia-alumina-silica and the like. The roof 22 of the glass-melting furnace 10 has a conventional curvilinear cross-sectional shape or crowned shape when viewed transverse to a longitudinal axis "A" of the channel, although the roof 22 may be of any suitable design. The roof 22 of the glass-melting furnace 10 is positioned above a surface 23 of molten glass 25. As is well known in the art, the glass-melting furnace 10 may optionally include one or more bubblers 24 and/or electrical boost electrodes (not shown). The bubblers 24 and/or electrical boost electrodes increase molten glass circulation and glass melting rates.

The glass-melting furnace 10 preferably includes two molten glass zones, a generally upstream melting zone 26 and a generally downstream fining zone 28. The melting zone 26 is considered the upstream zone of the glass-melting furnace 10 wherein

the glass-forming material 30 is charged into the glass-melting furnace 10 using a charger or charging device 32. The charging device 32 may be of any type suitable for depositing glass-forming material 30 into the glass-melting furnace 10. The glass forming material 30 may be a mixture of raw materials typically used in the manufacture of glass, such as for example glass batch. It will be appreciated that the glass-forming material 30 make-up is dependent on the type of glass product (not shown) being produced. Normally, the material includes silica-containing materials including finely ground scrap glass commonly referred to as cullet. Other glass-forming materials including feldspar, limestone, dolomite, soda ash, potash, borax and alumina may also be used. To alter the properties of the glass product, a relatively minor amount of arsenic, antimony, sulfates, carbon and/or fluorides may also be added. It will be appreciated that the molten glass 25 generally flows from the upstream end 6 of the glass-melting furnace 10 to the downstream end 8 of the glass-melting furnace 10, as indicated by the arrows 27.

Any suitable number and type of charging devices 32 may be employed to deliver the glass-forming material 30 into the glass-melting furnace 10. The illustrated glass-melting furnace 10 includes three charging devices 32 positioned in the charge end wall 14 and the two side walls 18a and 18b, respectively. As shown, the illustrated charging devices 32 are generally positioned at the upstream end 6 of the glass-melting furnace 10. The glass-forming material 30 is preferably delivered onto the surface 23 of molten glass 25.

The glass-forming material 30 forms a batch layer of solid or semi-melted particles on the surface of the molten glass 25 in the melting zone 26 of the glass-melting furnace 10. The floating solid batch particles of the glass-forming material 30 are melted principally by at least one burner, although a plurality of burners 34 are preferably used, as shown in Figures 1 and 4. The burners 34 are preferably oxygen-fuel burners, although any suitable type of burner may be employed. The burners 34 preferably provide a flame 36 of controlled shape and length. In a preferred embodiment of the invention the burners at the charging end 6 are mounted through the roof 22, as shown in Figures 1, 3 and 4. However, it is to be understood that the burners can be mounted in or through the charge wall 14 or the side walls 18a and 18b of the glass-melting furnace 10. The burners 34 melt the glass-forming material 30 and, at the same time, maintain the operating temperature of the surrounding refractory material within acceptable operating limits.

Significant quantities of combustion gases are generated by the oxidation of the gas from the burner.

After the glass-forming material is melted by the flames 36 and by heat radiated from other parts of the furnace, the molten glass flows from the melting zone 26 in the direction of directional arrow 27 to the fining zone 28. The molten glass exits the furnace 10 through the furnace throat 29, or through a channel known as a waist in the flat glass industry, as indicated by the directional arrow 31. In a preferred embodiment for specific glasses, the fining zone 28 includes at least one downstream burner 38 mounted in the roof 22 of the glass melting furnace 10. The downstream burner 38 can be similar in design to the burners 34. Optionally, any one or more of the upstream burners 34 can be mounted at an angle of up to about 20 degrees to the vertical to maximize convective and radiative heat transfer to the glass forming batch material. Likewise, the downstream end burner 38 can be mounted at an angle of up to about 20 degrees to the vertical to minimize and/or control foam formation on the glass surface 23 when operating with certain types of glasses such as fiberglass.

The glass-melting furnace 10 includes at least one exhaust 60, positioned at the downstream end 8, for removing the gases of combustion from the furnace. It is to be understood that alternatively a plurality of exhausts can be employed. For the glass-melting furnace 10 shown in Figures 1 and 2, the roof 22 of the glass-melting furnace 10 supports the exhausts 60. In a preferred embodiment of the invention, the exhausts are positioned outside the sidewalls 18a and 18b and supported in a different manner, as will be explained below.

In a preferred embodiment of the invention, the exhausts 60 are exhaust stacks for educting the combustion fumes and gases released from the decomposition of the glass-forming raw materials. It is to be understood that the exhausts can be any suitable type of opening or conduit for removing the fumes and gases from the furnace. Once the fumes and gases are removed from the furnace, they can optionally be treated in a manner to produce an environmentally friendly effluent. Where an exhaust stack is used, it can have a quadrilateral cross section, such as a square cross-section, although the exhausts 60 can have any suitable cross-sectional shape. In a preferred embodiment of the invention, the centerlines 72 of the exhausts are positioned at least about 70 percent of the distance from the charge end wall 14 of the glass-melting furnace to the discharge end wall 16 of the

glass-melting furnace, as shown, for example, in Figure 2. More preferably, the centerlines 72 of the exhausts are positioned at least about 80 percent of the distance from the charge end wall to the discharge end wall.

One of the advantages of providing the exhaust 60 in communication with the downstream end of the furnace is that there is a lower probability of any glass-forming materials to be entrained with the fumes and combustion gases. This is because the total mass flow of combustion products generated in the furnace of the invention does not pass over the glass forming materials, but instead only the combustion products from those burners upstream from the glass forming materials will pass over the glass-forming materials. In a conventional furnace the velocity of the gases will be greatest above the unmelted glass forming materials, thus enhancing the entrainment of these materials. In contrast, in the furnace of the invention, the velocity of the gases will not necessarily be the greatest above the glass-forming materials. Also, any glass forming materials entrained with the fumes and combustion gases will have a chance to settle out as the gases travel from the charge end 6 of the furnace to the downstream end 8. Another advantage in positioning the exhaust 60 in communication with the downstream end, particularly where the majority (more than 50 percent) of the burners 34 are positioned in the upstream end of the furnace, is that separation of the exhaust from the heat source eliminates a thermal short circuit that would occur if the burners and exhaust were positioned at the same end of the furnace.

An alternate embodiment of the glass-melting furnace 110 is shown in Figures 3 and 4. Features of the glass-melting furnace 110 having reference numbers the same as or similar to those of the glass-melting furnace 10 illustrated in Figures 1 and 2 have a similar function to those same features of furnace 10, unless otherwise indicated. The glass-melting furnace 110 includes two exhausts 60a and 60b. The exhausts 60a and 60b are in communication with the glass-melting furnace 110 and are operative to exhaust the gases of combustion produced by the burners 34 and 38. The exhausts 60a and 60b are positioned laterally outside the sidewalls 18a and 18b, respectively.

The exhausts 60a and 60b shown in Figures 3 and 4 include generally horizontal portions 64a and 64b and generally vertical portions 68a and 68b, respectively. The generally vertical portions 68a and 68b are spaced apart from the side walls 18a and 18b by the generally horizontal portions 64a and 64b, respectively. It should be noted that the

exhausts 60a and 60b include centerlines 72a and 72b, respectively. As is the case for the furnace 10 shown in Figures 1 and 2, the centerlines 72a and 72b are positioned at least about 70 percent of the distance from the charge end wall 14 of the glass-melting furnace 110 to the discharge end wall 16 of the glass-melting furnace 110, and more preferably at least about 80 percent of the distance from the charge end wall to the discharge end wall. Although the exhaust stacks are shown as being laterally spaced apart from the sidewalls, the exhausts could be integrally formed in the side walls themselves. In such a case, the innermost portion of the generally vertical portions 68a and 68b of the exhausts 60a and 60b would be included in the sidewalls 18a and 18b, respectively.

Yet another alternate embodiment of the glass-melting furnace 210 is shown in Figure 5. Features of the glass-melting furnace 210 having reference numbers the same as or similar to those of the glass-melting furnace 10 and the glass-melting furnace 110 have a similar function to those features of furnaces 10 and 110, unless otherwise indicated. The glass-melting furnace 210 shown in Figure 5 includes exhausts 60c and 60d, which have a quadrilateral cross section, although they may have any suitable cross-sectional shape.

The exhausts 60c and 60d can be supported in any suitable manner. The exhausts 60c and 60d may be positioned at any suitable location adjacent or on the discharge end wall 16 and/or the side walls 18 to exhaust the gases of combustion from the furnace. As shown in Figure 5, they can be separated laterally from the sidewalls 18. The exhausts 60c and 60d preferably include generally horizontal portions 64c and 64d and generally vertical portions 68c and 68d, respectively. The generally horizontal portions 64c and 64d are positioned above the surface 23 of the molten glass 25. The generally vertical portions 68c and 68d are spaced apart from the discharge end wall 16 and the side walls 18 by the generally horizontal portions 64c and 64d, respectively. In a preferred embodiment, the generally vertical portions 68c and 68d are operative to receive the gases of combustion and allow for removal in either the generally upward direction (indicated by arrows 76) or the generally downward direction (indicated by arrows 78).

The glass-melting furnaces 10, 110 and 210 all operate substantially similarly to produce molten glass 25. In operation, glass-forming material 30 is introduced to the upstream end 6 of the glass-melting furnace. Then, the glass-forming material is heated with the burners 34. The one or more burners 34 are preferably located at the upstream

end 6 of the furnace. The burners 34 form gases of combustion, which are exhausted from the downstream end 8 of the glass-melting furnace.

The glass-melting furnaces 10, 110 and 210 can be operated by introducing glass-forming material 30 to a charge half 80 of the furnace, as shown in Figure 2. As used in this context, the charge half 80 of the glass-melting furnace is understood to be that half of the glass-melting furnace nearest to the charge end wall 14. The glass-forming material 30 is heated with the one or more burners 34 located in the charge half 80 of the furnace. The burners 34 provide energy and form gases of combustion. The majority of the energy from all the burners associated with the furnace is introduced into the charge half 80 of the glass-melting furnace. Preferably, the energy from the burners introduced into the charge half of the furnace is at least twice the energy from the burners introduced to the discharge half of the furnace. The exhausts are positioned to exhaust the gases of combustion from the discharge half 84 of the furnace. As used in this context, the discharge half 84 of the glass-melting furnace is understood to be that half of the glass-melting furnace nearest to the discharge end wall 16. It can be seen that the exhausting of the combustion gases through the exhausts creates a flow of combustion gases within the furnace in a direction from the charge end wall of the furnace to the discharge wall of the furnace.

As shown in Figure 6, in another embodiment of the invention, a glass-melting furnace 310 can be provided with one or more exhausts 60e which connects through the end wall 16 to the downstream end 8 of the furnace. Where there is a single exhaust 60e centered on the end wall 16, it is likely that two channels or throats 29e would be used to discharge molten glass from the furnace 310. The exhausts are typically structured and arranged so that they exhibit a relatively lower ambient pressure than the pressure in the furnace. This can be accomplished by using an exhaust in the form of a stack. Alternatively, a fan could be used to lower the pressure within the exhaust. Also, a pressure differential is established between the upstream end 6 of the furnace and a downstream end 8 of the furnace, with the pressure in the downstream end of the furnace being lower than the pressure of the upstream end of the furnace. It can be seen that by exhausting the combustion fumes and gases via the exhaust 60, which is in communication with the downstream end 8 of the furnace, the pressure in the exhaust will be lower than the pressure in the downstream end of the furnace.

Referring now to Figure 7, there is shown a comparison of the temperature (y-axis) and corresponding percentage distance from the charge end wall (x-axis) of the glass-melting furnace to the discharge end wall. Thus, the temperature at the 75 percent distance is the temperature approximately three-fourths of the distance from the charge end wall to the discharge end wall. Likewise, the temperature at the zero percent distance is the temperature at approximately the charge end wall. Likewise, the temperature at the 100 percent distance is the temperature at approximately the discharge end wall.

A typical prior art glass-melting furnace heat profile is indicated at 200. It will be appreciated that the temperature at the approximate 75 percent distance is a relative peak compared to the temperature at the zero percent distance and the 100 percent distance. Thus, the temperature in a conventional glass-melting furnace at the zero percent distance is less than the temperature at the 75 percent distance. Other furnaces might have the peak temperature at different distances from the charge end wall, such as at the 50 percent distance or at the 100 percent distance. A heat profile for the glass-melting furnace according to the invention is indicated at 220. It can be seen that the temperature throughout the first 75 percent of the furnace from the charge end wall is well above that of a conventional furnace, and there is no relatively cold portion at the upstream end of the furnace, in contrast to the conventional furnace heat pattern 200. The relatively low temperature seen at the zero percent distance of the prior art heat profile (graph 200) is not seen with the heat profile (graph 220) for the glass-melting furnace according to the invention. The comparatively higher temperature at the zero percent distance indicates that more efficient energy utilization and glass batch melting is expected with the glass-melting furnace according to the invention. If the furnace is operated with a slightly greater energy input than was the case for the furnace represented by graph 220, the temperature profile will be more elevated at the charge end of the furnace, as shown at graph 222. Likewise, if the furnace is operated with a slightly less energy input than was the case for the furnace represented by graph 220, the temperature profile will be slightly lower at the charge end of the furnace, as shown at graph 224.

Although the invention has been described in detail with reference to certain specific embodiments, those skilled in the art will recognize that there are other embodiments within the spirit and scope of the claims enclosed herewith.